# IMPLICIT GRAPHEMIC CUES IN THAI READING

BY

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THESIS

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# Abstract

Languages that do not use space or other punctuation to demarcate word boundaries typically show improvements in early reading time measures when spaces are inserted. However, it seems that Thai may not follow this same trend (Winskel, Radach, & Luksaneeyanawin, 2009). One potential explanation is that Thai orthography may provide other cues that guide readers in word segmentation, even in the absence of explicit word boundary punctuation. A self-paced reading experiment investigates the role that visual salience of graphemes that appear above or below the main line of text plays in word segmentation and reading. Visual salience was operationally defined by the physical size of the grapheme, manipulated by font size specification. The necessity for the reader to segment the words themselves was manipulated by changing the windowing for a key target region in each sentence, such that normal windowing (i.e., normal segmentation) meant that all words were presented one at a time in the self-paced reading paradigm. In abnormally-segmented conditions, the self-paced window boundaries were shifted to include the target word as well as part of the neighboring words. Mis-segmentation and grapheme size yielded significant main effects, and the interaction between the two factors was significant ($p=0.03298$), indicating when segmentation was left up to the reader, the shrunken graphemes caused a greater slow-down than when segmentation was done properly for them by the self-paced windowing paradigm. Thus, Thai readers parse text more effectively when graphemes in the special vertical position are larger, showing that graphemes in vertical position act as cues for Thais in reading unspaced text.

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# 1 Introduction

Punctuation (including space) has the power to join and divide. For a reader, it can group phrases, help segment words, and help plan eye movements within those phrases. In nearly all of the most commonly taught languages, spaces separate words, as in this very sentence. During normal reading of languages such as English, the planning of eye movements is informed and facilitated by the presence of spaces between words. When the spaces in English are removed, studies have shown that reading deteriorates, and eye movements are executed less optimally (Juhasz, Inhoff, & Rayner, 2005; Pollatsek & Rayner, 1982; Rayner, Fischer, & Pollatsek, 1998). One way to interpret this is that the spaces serve to help the eyes identify the boundaries of words. However, since English is normally written with spaces, an alternative explanation is that reading without the spaces is unnatural for readers of English and therefore more difficult.

The Thai writing system presents an interesting contrast to English, because it is normally written without spaces between words (see **Table 1**).

**Table 1. Sample of Thai Text**[1]

| |
|---|
| ระดับมลภาวะในกรุงปักกิ่งของจีน<br>อยู่ในขั้นร้ายแรงเหนือระดับที่องค์การอนามัยโลกระบุว่าเป็นอันตรายต่อมนุษย์ |

Since Thai does not use space as a separator between words, the question arises as to how readers plan their eye movements and whether reading without spaces is detrimental when that is how readers are accustomed to seeing the language. Moreover, if there are not explicit cues to segmenting the words, yet reading without spaces is not as detrimental to Thai readers as it is for readers in other languages, then are there systematic patterns in the writing system that aid in word segmentation? This study focuses on the effect of certain salient vowel graphemes as cues to syllabification or segmentation of words in Thai text.

## 1.1 Thai Orthography

Thai is read from left to right. The placement and shape of certain vowel graphemes in Thai may provide a visual cue salient enough to facilitate planning the next eye movement in the

[1] *Taken from headline of Matichon newspaper, online at www.matichon.co.th (13 January 2013)*

absence of spaces. In particular, certain vowels are placed before, above, or below their syllable onset consonant. In the following examples, a dash (-) represents where the onset consonant letter would appear in relation to the vowel letters. In all cases the vowel is pronounced after the consonant, regardless of the visual orientation of the graphemes (to the right, to the left, above, or below).

**Table 2. Direction of the vowel character relative to onset consonant**

| | to the **Right** | to the **Left** | Above | Below |
|---|---|---|---|---|
| Thai characters | -ะ -า | ไ- ใ- เ- แ- | ิ ี ึ ื ั | ุ ู |
| Sound (IPA) | a a: | ai ai e ɛ | i i: ɯ ɯ: a | u u: |

Notice that the vowel graphemes representing the sound /ai/ (ไ and ใ) have ascenders and are therefore taller and more salient. Vowels written above or below the consonant are also inherently salient because they appear in a different vertical orthographic position (VOP) than is occupied by most of the other graphemes. This gives them a particular visual salience in the parafovea (i.e. the region within one's visual field peripheral to the area with the greatest visual resolution). These vowels could serve as systematic visual cues for onset consonants, and thus also for word boundaries (though less perfectly for the latter). It should be noted, though, that not all vowels are necessarily visually salient in this way. In particular, consider the vowels written to the right of the consonant. Also, some syllables have unwritten, assumed vowels, thus making the syllabification of adjacent consonants difficult.

## 1.2 Eye Movements and Reading

During the reading process, the eyes progress through text alternating between fixations and saccades (quick eye movement between fixations). While fixating on one portion of text, a plan is made regarding where to fixate next. Within a certain spatial range (the visual perceptual span[2]), readers can perceive visual orthographic information of graphemes outside of the fovea (the center of one's field of vision where sensation is most acute). This parafoveal information allows the reader to begin processing visual characteristics of upcoming text. Letter identity, upcoming punctuation, or other low-level perceptual information may be gleaned this early

[2] Perceptual span is often operationally defined as the distance from the center of the fovea that a disruption in reading occurs when orthographic information is missing or modified (Rayner & Pollatsek, 1989, p. 124).

(Pollatsek & Rayner, 1982). The more processing that occurs during parafoveal preview, the less time the reader may need to fixate directly on that portion of upcoming text, sometimes skipping it altogether (for short or contextually predicted words). Space is one example of a cue that, when processed parafoveally, can improve the planning and execution of the next eye movement.

Parafoveal preview has been measured in eye tracking experiments using what is called a boundary change paradigm. A boundary change paradigm takes into account where the center of the fovea is and at a certain distance from the fovea makes changes to the visual stimuli when a certain boundary is crossed. When text in the parafovea has one form yet has a different form when fixated, the effect of parafoveal preview can be separated from foveal processing. If certain information is either present or absent in the parafovea, it will only affect processing (for better or worse) if it fits within the distance from the fovea that is within the perceptual span and thus readers can process it and take it into account.

## 1.3 Effect of Thai writing system on eye movements

Winskel, Radach, & Luksaneeyanawin (2009) studied the effects of the presence or absence of spacing between words in reading English and Thai. Participants in the study included English monolinguals and Thai-English bilinguals. Both groups of participants read English sentences with and without spacing; the bilinguals also read Thai with and without spacing. Lexical frequency of the target word was also manipulated.

Winskel and colleagues hypothesized that, if spacing helps with word segmentation, then reading either English or Thai with spacing would increase reading speed and improve first fixation landing position within word. Rayner (1998) gives an overview of viewing location within a word and makes a distinction between Optimal Viewing Position (OVP) and Preferred Viewing Location (PVL). The OVP would be the center of the word, because it allows the reader to gain as much information about the word in a single fixation as possible. Actual performance by readers, on the other hand, shows that they tend to fixate between the center and the beginning of the word, which is the PVL. Couched in these terms, Winskel et al. (2009) hypothesized that spacing would allow readers of Thai to fixate closer to the OVP (or at least the PVL), whereas reading without spaces would cause first fixations to be closer to the beginning of the word (Rayner, Fischer, & Pollatsek, 1998).

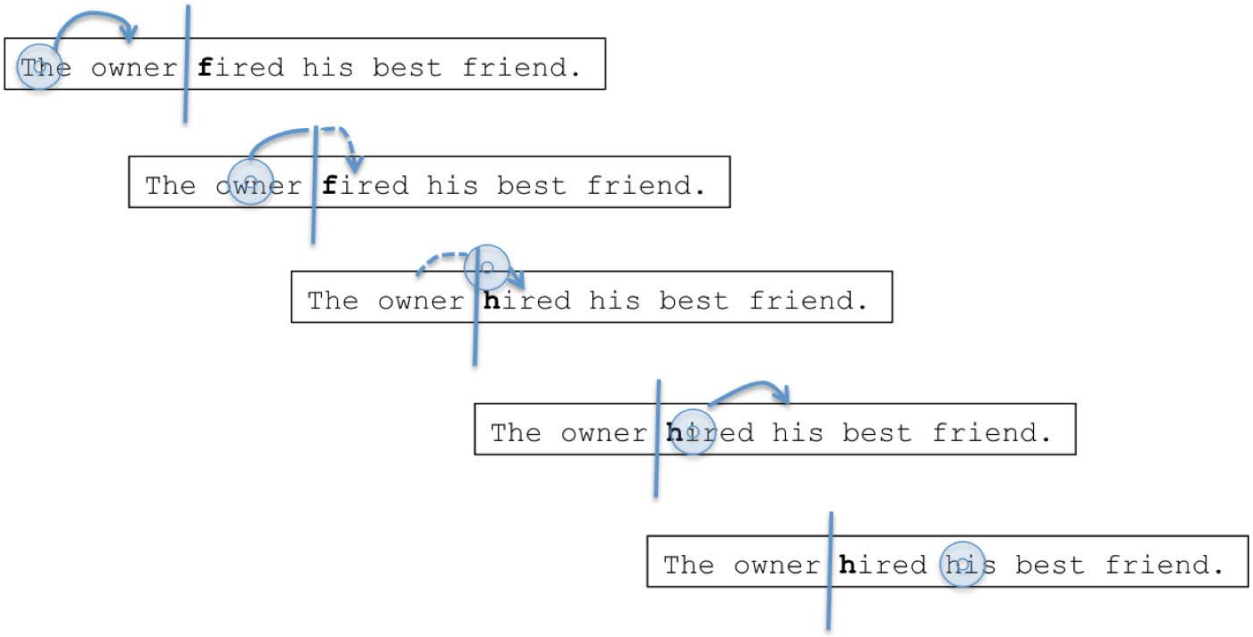
For whole sentence measures, they found that the monolingual English readers read the unspaced condition more slowly than the spaced condition. The Thais read the unspaced English sentences even slower relative to the spaced English sentences. However, when reading Thai, the bilinguals read the unspaced condition slightly faster. Possible explanations for this could include: (a) They are more used to reading Thai without spaces; (b) without spacing, better preview effects of the text downstream can be obtained and therefore skipping can occur more; and (c) without spacing, the sentences occupy a shorter linear distance, which therefore the eyes can traverse more rapidly.

For early reading time measures related to the target words, they found some of the patterns of effects that they hypothesized. For instance, measures such as gaze and fixation duration were longer in the unspaced conditions for the bilinguals reading both Thai and English. The same trend was found with the English monolinguals. In all conditions, fixation duration was longer for lower frequency words. However, the hypothesized interaction between spacing and frequency was not observed.

The authors' hypothesis about first fixation landing position within the target words was unsupported. Spacing, or the lack thereof, in Thai did not affect landing position in their study. This may be because many details (such as default tone, tone markers, and vowel position) are determined by the onset consonant cluster. This might then require the reader's focus to be closer to the beginning, even when segmentation is not an issue.

The advantage that was found for native speakers reading un-spaced Thai could simply be the result of convention and experience, but Winskel later tested the importance of parafoveal preview in Thai using a *boundary change* experiment (2011; for first use of boundary change paradigm, see Rayner, 1975). In this paradigm, one version of the text is presented in the reader's parafovea, but as the reader's gaze crosses a pre-determined boundary and the text enters the fovea, the text is changed (see example in Figure 1). In Winskel's study, when the wrong vowel was presented before crossing this boundary, reading times were only affected by parafoveal vowel manipulations when the vowel was in Horizontal Orthographic Position (HOP), i.e. to the left or right of the consonant. In contrast to vowels, when tone markers in VOP were manipulated parafoveally, reading time suffered.

**Figure 1. Boundary Change Paradigm: Mechanics of the change**




Thai readers process *orthographic* information in their parafovea, but *phonological* information is not yet processed at the preview stage (Winskel, 2011). As described above, each Thai vowel grapheme is assigned one of four locations relative to the onset consonant: above, below, left, or right. Since Thai is read left to right, vowels that appear left of the onset consonant thus force a misalignment between the serial order of graphs and the temporal order of the corresponding phones. This is a normal trait of Thai orthography, not an artificial manipulation. For sentence contexts, there is evidence that words containing misaligned vowels are read more slowly than words without (Winskel, 2009).

## 1.4 Testing the Role of VOP in Word Segmentation

The work by Winskel and colleagues just described suggests that it is the *visual salience* of graphemes written in Vertical Orthographic Position (VOP) that influences the efficacy with which readers of Thai segment text in the absence of inter-word space. Because Thai is read from left to right, the left-to-right order of the consonant characters represents the order in which those consonants are pronounced. Each vowel grapheme has a consistent position with respect to the onset consonant, located in one of the four cardinal directions from the consonant (as seen in Table 2). Therefore, any vowel character—and the knowledge of where that grapheme must be positioned—provides deducible information about the location of the beginning of a syllable.

Although reading processes in Thai may typically progress at the word level, many words in Thai are monosyllabic, so letters in VOP often coincide with word-beginnings as well. If vowels are used as word boundary cues, then those that are more visually salient would be even stronger cues in the parafovea than the less salient ones. However, just because the vowels are deducible as cues for word segmentation, there is no evidence from reading behavior studies that demonstrate that they are actually *used* as cues in the fovea or parafovea.

In order to test the role of VOP in Thai word segmentation, this experiment manipulated the visual salience of vowels (and other graphemes that appear in VOP), as well as the segmentation (grouping) in which the words are revealed in a self-paced reading paradigm. To manipulate the visual salience of graphemes in VOP, the font size of the vertical graphemes was shrunk to half the font size of the other graphemes in one condition, while leaving them normal-sized in the other. The font size manipulation did not affect the left-to-right linear distance of the sentences, thus avoiding the confound present in Winskel et al. (2009). The segmentation into words was manipulated for a single target word within each sentence by re-segmenting it with the nearest neighboring letter from either side of the target word (mis-segmented condition).

The design of this experiment allowed for at least two opposing patterns of results and, by extension, two opposing conclusions. Slower reading times on mis-segmented trials would be expected, since it amounts to an inaccurate cue to word boundaries. However, such a main effect alone does not clarify whether letters in VOP facilitate word segmentation. Rather, the difference lies in whether there is an interaction between the visual salience and segmentation manipulations. A main effect of visual salience of graphemes in vertical position but without an interaction with segmentation would show that those graphemes are important for word recognition but would give no reason to conclude that they aid specifically with word segmentation. Alternatively, the salience of the vertical graphemes could affect word segmentation specifically, and not just broader word recognition processes. In that case, salience would not affect a reader's ability to segment words when the letters are already correctly grouped in the properly-segmented condition. In contrast, an interaction effect of visual salience would manifest itself in the mis-segmented condition, meaning that the cue is specifically helpful when the task of segmentation is made more difficult.

# 2 Method

## 2.1 Participants

Twenty-four native speakers of Thai (13 female) participated in this experiment. All were living in the Champaign-Urbana, IL area, most of them pursuing undergraduate or graduate studies at the University of Illinois at Urbana-Champaign. All participants had normal or corrected-to-normal vision and were paid $10 for their participation.[3] Ages ranged from 18 to 36, with a mean age of 26.3. While all participants were native speakers of Thai, they were also literate in English. For more detailed information, please see the charts included in the appendix (§7.1).

## 2.2 Stimuli

One hundred twelve experimental sentences and six practice sentences were constructed by a native speaker of Thai. Four images of each sentence (for a total of 448 images) were created by crossing two factors, each with two levels: font size and segmentation. For the **font size factor**, one condition of each sentence showed all graphemes as equivalently sized, while in the manipulated condition, all VOP graphemes were shrunk to half their original size. The shrunken condition left the VOP letters horizontally centered over the consonant letter in the mainline and did not affect the spacing between the mainline letters. (*See example of font size manipulation in* Table 7.) As for **segmentation**, in one condition, all words were properly segmented. In another condition, all words but the target word and the words directly preceding and following the target were properly segmented. The target word was mis-segmented by incorporating the final letter of the preceding word and the first letter of the following word (including any graphemes above or below). It should be noted that the target word was the same in each set of four sentences, allowing for comparison among the conditions without needing to account for differences due to lexical frequency.

[3] This study was made financially possible thanks to a 2012 Cognitive Science / Artificial Intelligence Award from the Beckman Institute for Advanced Science.

**Table 3. Experimental Conditions**

| | Normal Size | Shrunken |
|---|---|---|
| Properly Segmented | Properly Segmented<br>Normal Size | Properly Segmented<br>Shrunken |
| Mis-Segmented | Mis-Segmented<br>Normal Size | Mis-Segmented<br>Shrunken |

The target word for each sentence had at least one vowel or tone diacritic in Vertical Orthographic Position (from the set ิ ี ึ ื ั ้ ่ ๊ ๋ ็ ์ ุ ู). The target word was never the first or last word of the sentence, since initial and wrap-up process can inflate reading times in those positions. The majority of the target words were at least 2 regions from the beginning or end of the sentence, and only seven of the targets were the second or penultimate word of the sentence.

The length of each sentence was limited in order to ensure that all stimuli appeared on a single line when presented on the screen for the self-paced reading study. In order to quantify the length of sentences, it is useful to define a measure called **horizontal orthographic units**. Since some graphemes in Thai (such as tone marks and certain vowels) are written above or below another character, they do not by themselves occupy horizontal space. In contrast, all consonants, other vowels, and certain punctuation do necessitate additional horizontal space for each grapheme (in typography terms, they have a positive *advance width*). The count of the characters in a string that necessarily occupy horizontal space shall be referred to as the string's length in **horizontal orthographic units (HOU)**.

**Table 4. Characters counted for Horizontal Orthographic Units**

| |
|---|
| กขฃคฅฆงจฉชซฌญฎฏฐฑฒณดตถทธนบปผฝพฟภมยรฤลฦวศษสหฬอฮะาแเไๅๆฯ฿◉๏๐๑๒๓๔๕๖๗๘๙.1234567890 |

Sentences with a variety of syntactic structures and topics were used so that findings could be as widely generalizable as possible. Sentence widths also varied (in HOU), in part due to the variety of syntactic structures, as well as to the varying lexical content. The minimum width was 29 horizontal units, and the maximum was 82 units. Table 5 summarizes the sentence widths, and Appendix §7.5 contains the full list of sentences used.

**Table 5. Summary of widths of items, in HOU**

| Minimum | 1st Quartile | Median | Mean | 3rd Quartile | Maximum |
|---|---|---|---|---|---|
| 29.00 | 51.00 | 62.00 | 60.53 | 69.00 | 82.00 |

Each sentence was presented in a word-by-word, self-paced reading fashion and was followed by a true/false comprehension task. The entire question was presented at once, and participants were asked to judge it as either true or false based on the preceding sentence. Each item had just one comprehension question associated with it, and the items were devised so that half were true and half were false.

The sentences were segmented into individual words, although determining what constitutes a word is not as straightforward a task for Thai as it is for English. In English, a writer signals what they consider to be a word by placing spaces on either side. Prescriptive norms stating which strings can stand alone as words are propagated at the level of society and educational systems, and are inherent in dictionaries.

Thai, on the other hand, is not written with punctuation (such as space) demarcating each word. Thus, other criteria are needed to determine word boundaries. Individual morphemes should not span across a word boundary, so identifying morpheme boundaries could be one strategy employed by Thai readers. While Thai does have polysyllabic words, syllable information can narrow down possible locations for word boundaries. Finally, corpus statistics about morpheme or syllable co-occurrence could help decide whether a group of syllables or morphemes should be considered multiple words or just one compound word. Haruechaiyasak and colleagues implemented various dictionary-based and machine-learning-based algorithms, and found that the machine-learning ones performed better (2008).

The sentences in this study were segmented using a program that maximizes the likelihood of collocation based on corpus statistics. The software was written by Wirote Aroonmanakun of Chulalongkorn University (2002a; 2002b). The program succeeded in segmenting most of the sentences and failed for only a few of the sentences (due to out-of-vocabulary words). In the few failed cases, segmentation was done manually by the author (who is literate in Thai).

One of the manipulations in this experiment was the mis-segmentation of word boundaries. In trials designated for the mis-segmented condition, the window boundaries

surrounding the target word (the regions of text that are seen simultaneously) were shifted outwards by one Horizontal Orthographic Unit, thus including the nearest consonant (and vertically placed graphemes, if any) of the neighboring words.

**Table 6. Segmentation manipulations**

| Example | / = window boundaries; underlining = target word |
|---|---|
| Normally Segmented: | ทาง / สังคม / ปัจจุบัน |
| Mis-Segmented: | ทา / งสังคมปั / จจุบัน |

Images of the sentences as well as pixel coordinates of the window boundaries were generated using the Python Imaging Library (Lundh, 2009). Images of the text of font size 50 (main line) and 25 (Vertical Orthographic Position) were generated on top of a white background of size 2560x100 pixels and were saved as PNG files. A truncated example of a single item in normal and shrunk form appears in Table 7.

**Table 7. Shrunk Condition Example**

| Normal, Uniform Font Size |
|---|
| ชาวล้านนามีวิธีการท้าน้ำพริกหลายวิธีซึ่งแตกต่างกัน |
| Graphemes in VOP Shrunk to half normal size |
| ชาวล้านนามีวิธีการท้าน้ำพริกหลายวิธีซึ่งแตกต่างกัน |

Stimuli were presented visually one window of text at a time on a 20" CRT monitor (Sony Trinitron MultiScan 500-PS) using a resolution of 1280 x 800 and refresh rate of 75 Hz.[4] One horizontal orthographic unit (one letter) occupied 0.45 degrees visual angle. The experiment was administered using Experiment Builder, software developed and licensed by SR Research Ltd. (Canada). Trials started with a fixation point on the left side of the screen, where

[4] Note that the sentence images were saved with a width precisely twice the number of pixels as the screen resolution. The images were resized to 1280 x 50 pixels by the Experiment Builder software.

the first word would appear. Participants were instructed to look at the fixation point and press a button on a Gravis PC Gamepad controller in order to begin the trial. They pressed the same button each time they were ready to advance to the next word. Timing of all button responses was recorded. For the true/false statement that was presented after each trial, true and false responses were made by pressing a second and third button on the Gamepad, meaning that each of the three response buttons used had a dedicated response. The Gravis PC Gamepad was connected to a Dell computer via serial port, and responses were recorded using the TTL trigger node in Experiment Builder, which is capable of more accurate recording of response times than mice, keyboards, and USB-attached peripherals (according to SR Research).

## 2.3 Analytical Methods

Accuracy was then calculated for each trial. For each window, reading time was measured as the latency between presses of the button to advance. The critical region consisted of the target word and the windows immediately preceding and following the target word (target ± 1). The reason for including these three windows is that due to the segmentation manipulation, the length of the target window varies across conditions, while the length of the 3-window region does not vary. Moreover, processing costs and benefits of a given region can carry over into the following region in self-paced reading.

# 3 Results

## 3.1 Comprehension Questions

Speed and accuracy were recorded for the comprehension questions, and reading time was measured for each window. Overall, participant accuracy was high (M = 95.4, SD = 3.4), as was accuracy by item (M = 95.4, SD = 7.1). The two histograms below show the distribution of accuracy when grouped by subject and by item. The latencies for responding to the comprehension questions were typically between 2 and 6 seconds.

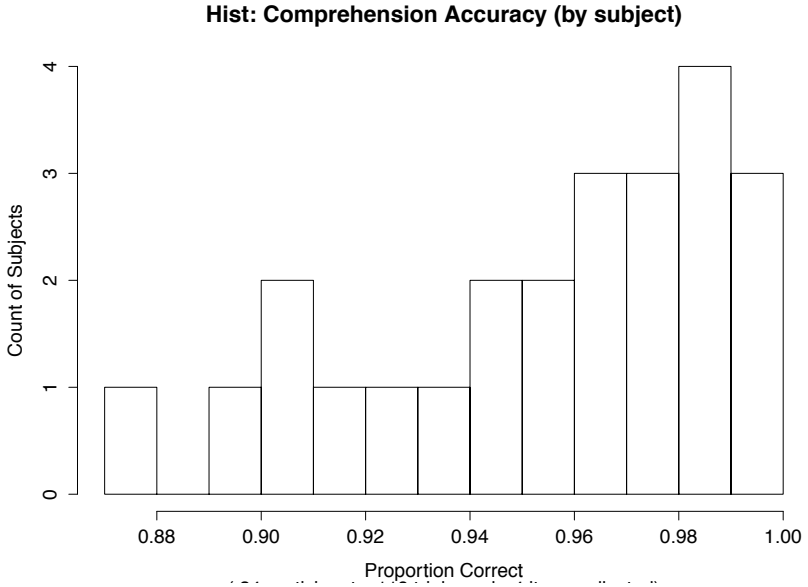



**Figure 2**

Figure 2 verifies that the overall comprehension accuracy was high. Two subjects out of 24 had accuracy below 90%. Subjects' accuracy ranged from 87.3% to 99.1%.

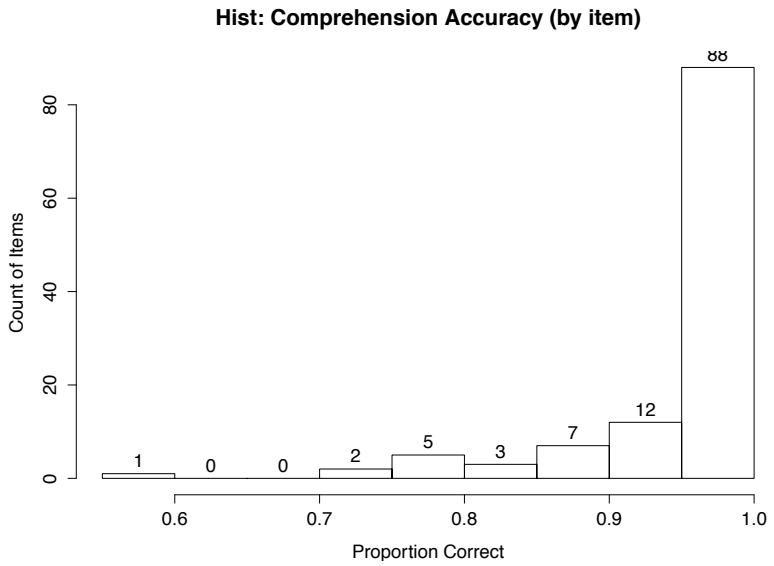



**Figure 3**

Figure 3 shows that most of the items were unambiguous, with only one item on which participants were split. The answers considered correct were the ones chosen by the majority of participants, which agrees with the answer key made by the creator of the stimuli for 97% of the items.

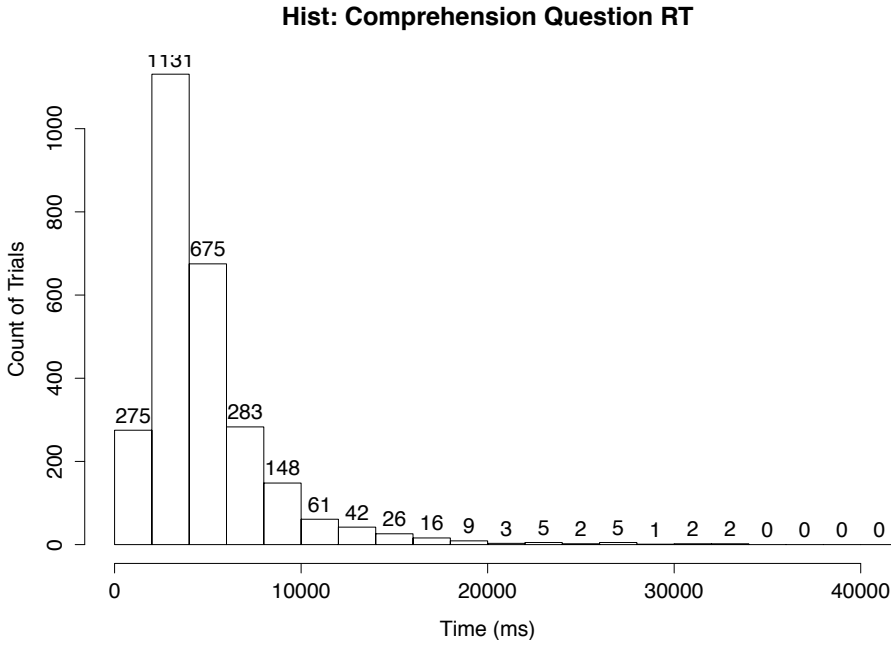



**Figure 4**

The distribution of reaction times on the comprehension questions (Figure 4) shows that most responses were made between 2 to 6 seconds.

## 3.2 Reading time

### *3.2.1 Target Word Reading Time*

Figure 5 and Figure 6 illustrate the typical duration spent on the target words, aggregated by subject. Overall, they spent half a second on the target word itself.

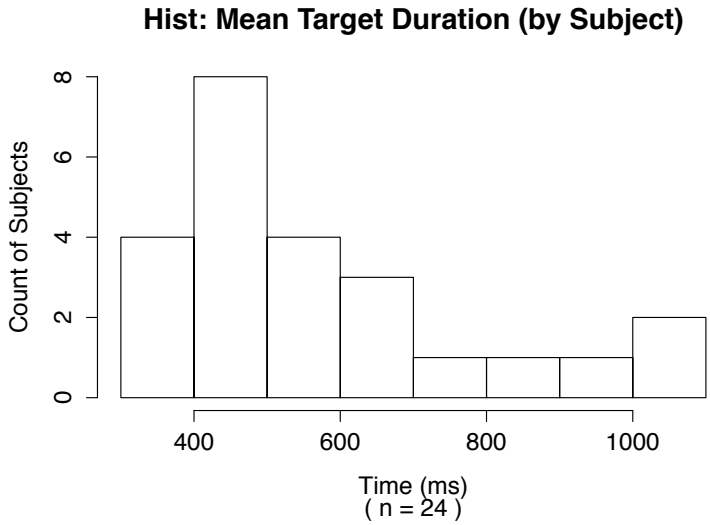



**Figure 5 Target Word Duration by Subject**

```
Summary of Mean Target Duration (ms) by Subject
   Min. 1st-Quartile  Median    Mean 3rd-Quartile    Max.
  309.1        427.3   499.9   567.2        645.1  1042.0
```

**Figure 6 Quartiles and mean of target word durations, collapsed by subject**

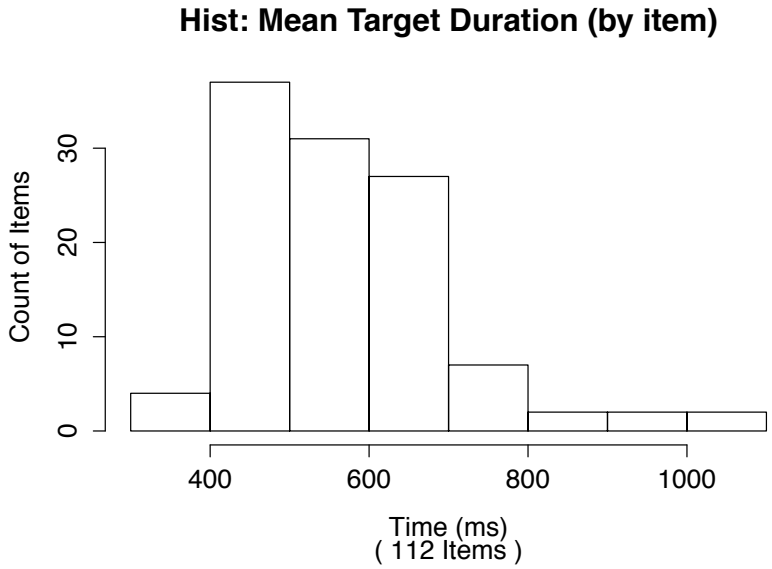



**Figure 7 Target Word Duration by Item**

Figure 7 shows the distribution of mean target durations when aggregated by item.

```
Target Durations aggregated by Item
   Min. 1st Quartile  Median    Mean 3rd Quartile    Max.
  377.1        472.9   552.5   567.2        623.9  1085.0
```

**Figure 8 Quartiles for the distribution of mean target durations when aggregated by item**

| **Reading Times (Target word only)** | | Duration (ms) | Standard Error of the mean |
|---|---|---|---|
| Mis-segmented | Shrunk | 697.9 | 20.0 |
| | Not Shrunk | 628.5 | 18.3 |
| Segmented | Shrunk | 472.2 | 12.6 |
| | Not Shrunk | 470.1 | 15.8 |

**Figure 9. Target Word Reading Times by Condition**

The typical target word reading time, by participant and by item, was about 500 ms. The summary of target word reading times by condition (Figure 9) indicates trends of a main effect of segmentation such that the mis-segmented condition slowed reading on the target by about 120 ms. The means of the shrunken condition versus normal size was only 38 ms different (shrunken slower), which is within one standard error of the mean, meaning that they may come from the

same distribution. The difference between font size conditions increased by 70 ms from the segmented to the mis-segmented condition, hinting at an interaction. As reasoned in §1.4 on page 6, an interaction in this direction would support the hypothesis that VOP salience is used as a segmentation cue.

### *3.2.2 Target Region Reading Time*

Two problems emerge from looking only at target word duration in milliseconds. First, the target window is two letters longer in the mis-segmented condition, which is a confound to consider when interpreting the longer reading duration reported for that condition. To deal with the target window / segmentation confound, the word preceding and following the target should be included in the critical region. The length of that three-word region did not vary across conditions, making for the most equitable comparison.

The second problem is that the raw reading times in Figure 10 exhibit strong positive skew (as any reading or reaction time data naturally do), making many data points look like outliers. One way of handling the reading time skew is to use a logarithmic transformation (Ratcliff, 1993). Figure 11 illustrates the relationship between the shrunken graphemes and missegmented words manipulations. The graph type is a notched box plot. Each box represents the first and third quartiles. The notch is centered on the median, and if the notch's height (a fraction of the interquartile range) does not overlap with another notch, the medians may be reliably different. The dependent axis scale is $\log_{10}$, although the labels are converted to milliseconds to make them more interpretable.

The comparisons of reading times above do not take into account individual differences between participants and between items. In the next sub-section, these variables are incorporated in a mixed effects model, providing a more sensitive look at these patterns.

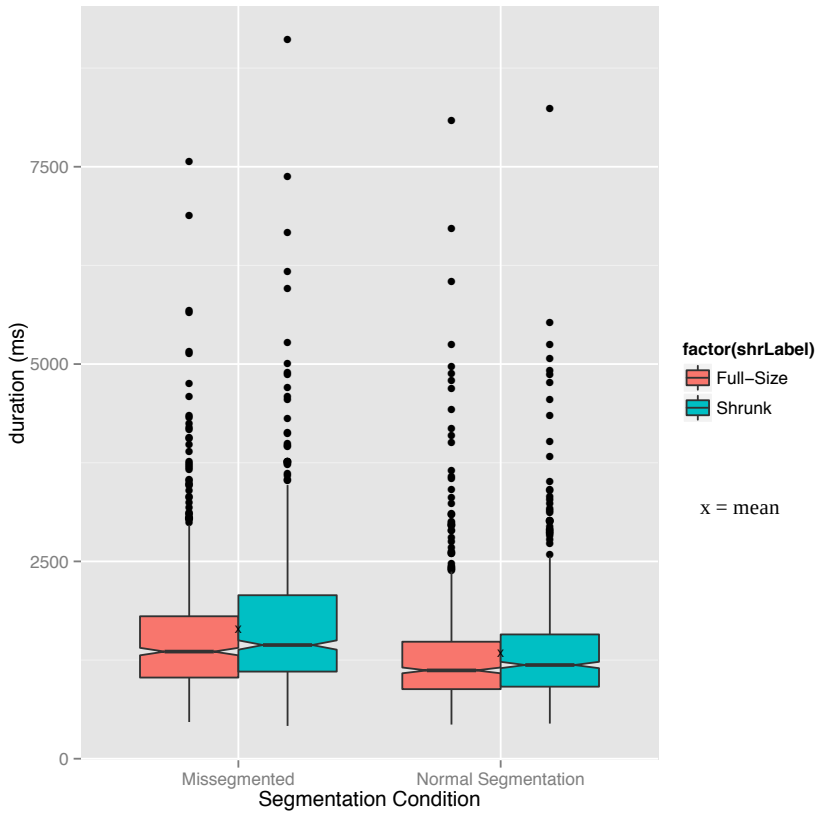



**Figure 10. Duration of the target region (target window plus the two adjacent windows)**

Figure 10 illustrates the relationship between the shrunk graphemes and missegmented words manipulations. The graph type is a notched box plot. Each box represents the first and third quartiles. The notch is centered on the median, and if the notches height (a fraction of the interquartile range) does not overlap with another notch, the medians may be reliably different. The scale is in milliseconds.

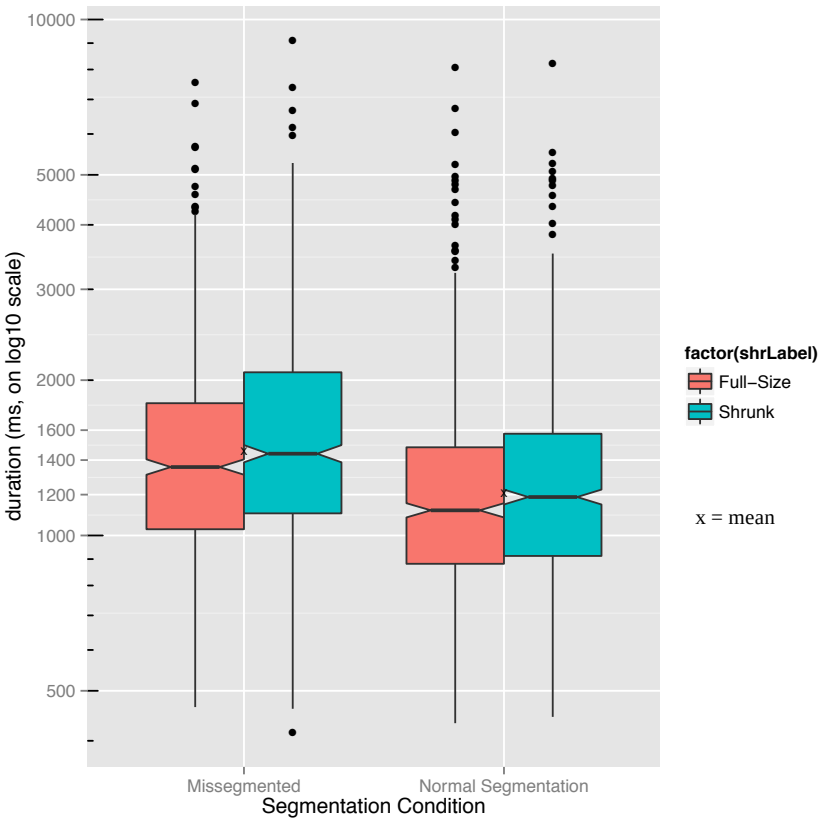



**Figure 11. Reading time of expanded target region (target window plus the two adjacent windows). Dependent axis is scaled as $\log_{10}$(ms), but the labels are converted to raw milliseconds.**

| Missegmented | shrunk | Mean log(dur) | StDev | N | StErr |
|---|---|---|---|---|---|
| 0 | 0 | 3.0743 | 0.0353 | 672 | 0.0072 |
| 1 | 0 | 3.1449 | 0.0380 | 672 | 0.0075 |
| 0 | 1 | 3.0891 | 0.0355 | 672 | 0.0073 |
| 1 | 1 | 3.1832 | 0.0415 | 672 | 0.0079 |

**Figure 12**

Figure 12 summarizes the logarithm of target region (target word plus preceding and following word) reaction time.

## 3.3 Mixed-Effects Models

The **full mixed-effects** model contained the following **fixed factors**: font-size, segmentation, and the interaction between the two. Two **random factors** were also included: subject and item. The model estimate for the intercept (target + neighbors) is 10^3.07 ms (1187 ms), and the estimates of the effect sizes (added to the intercept) are approximately: shrinking adds 41 ms, mis-segmentation adds 209 ms, and on trials where both manipulations occurred, reading slowed an additional 66 ms beyond the main effects. The t-values show a large segmentation effect (t=9.05). The shrunken VOP factor had a smaller, marginally significant t-value (t=1.89); however, the interaction term was significant (t=2.13). See Table 8 below for the summary of the full model.

**Table 8. Statistical summary of the Full Mixed-Effects model**

```
Formula: log10(duration) ~ shrunk + misseg + shrunk*misseg
           + (1|subj) + (1|itemid)

   AIC   BIC logLik deviance REMLdev
 -2539 -2498   1276    -2553   -2523

Random effects:
Groups   Name        Variance  Std.Dev.
 itemid   (Intercept) 0.0031671 0.056277
 subj     (Intercept) 0.0139843 0.118255
 Residual             0.0204335 0.142946
Number of obs: 2688, groups: itemid, 112; subj, 24

Fixed effects:
                     Estimate Std. Error t value
(Intercept)          3.074291   0.025325  121.39
shrunkTRUE           0.014768   0.007798    1.89
missegTRUE           0.070575   0.007798    9.05
shrunkTRUE:missegTRUE 0.023527   0.011029    2.13
```

The **Reduced Model** differs from the full model only in removing the interaction term. The interaction is the critical effect necessary to provide strong evidence that readers use graphemes in VOP to aid word segmentation. If the reduced model fits the data much worse than the full model, then the interaction accounts for significant variability. Table 9 shows the summary of the Reduced Model without interaction.

**Table 9. Reduced Model (excludes the Interaction)**

```
Formula: log10(duration) ~ shrunk + misseg + (1|subj) + (1|itemid)

   AIC   BIC logLik deviance REMLdev
 -2536 -2501   1274    -2548   -2526

Random effects:
Groups   Name         Variance  Std.Dev.
 itemid   (Intercept) 0.0031656 0.056263
 subj     (Intercept) 0.0139839 0.118253
 Residual             0.0204700 0.143073
Number of obs: 2688, groups: itemid, 112; subj, 24

Fixed effects:
            Estimate Std. Error t value
(Intercept) 3.068410   0.025172  121.90
shrunkTRUE  0.026531   0.005519    4.81
missegTRUE  0.082338   0.005519   14.92
```

The Akaike Information Criterion (AIC; similar to the Bayesian Information Criterion) is used to compare the amount of information a given model preserves relative to the most effective model within a set of models (Akaike, 1974; for comparison of AIC and BIC, see Burnham & Anderson, 2004). AIC is derived from a likelihood computation. The model with the lowest AIC (most negative) is the best, and the AIC of all the other models is logarithmically scaled (base=e) relative to that best model, resulting in the Relative Likelihood. The AIC and Relative likelihood for various versions of the mixed effects model are shown below in Figure 13. More details about each model can be found in Appendix section 7.2. The probability of the reduced models relative to the full model was calculated using the likelihood ratio test. The interaction in the full model was statistically significant (p=0.03298), and according to the parameter estimates of the full mixed effects model (Table 8), the interaction had a larger effect size than the main effect of shrunken font size. The conclusion drawn from these comparisons is that the interaction added significantly to the model fit.

| | AIC | Relative Likelihood | p-value |
|---|---|---|---|
| **Full Model** | -2539 | 1 | |
| **Drop Interaction** | -2536 | 2.799e-01 | < 0.033 |
| **Drop Shrunk & Interaction** | -2515 | 7.692e-06 | 1.041e-06 |
| **Drop Items (rand)** | -2329 | 2.831e-46 | |
| **Drop Misseg and interaction** | -2325 | 3.497e-47 | 2.2e-16 |
| **Subject & Item only** | -2306 | 2.408e-51 | 2.2e-16 |
| **Drop Subject (rand)** | -1258 | 7.428e-279 | |

**Figure 13. Akaike Information Criterion and Relative Likelihood, sorted**

# 4 Discussion

This experiment tested the influence on Thai word segmentation exerted by the visual salience of vowel and tone graphemes that are written above or below the consonants. The challenge to word identification due to mis-segmentation was the most reliable and strongest factor to cause slower reading times on target words. Reducing visual salience of vertically placed vowels negligibly slowed reading in the properly-segmented condition, which is analogous to the finding in Winskel (2011), in which manipulated grapheme identity for vowels in VOP did not disrupt reading. However, the significant interaction between segmentation and vowel salience in this study demonstrates that those vowels in VOP are important to visual word segmentation in Thai – an observation that is novel to the present study.

The visual salience of Thai vowel graphemes—specifically, their extension above and below the vertical plane—has a subtle yet robust effect on word segmentation during reading. The subtleness likely means that it is one of several potential cues to segmentation, but nevertheless one that has been heretofore unattested.

## 4.1 Further study

The results of this self-paced reading require further testing with a more sensitive paradigm that reflects a more natural reading process. Performing a similar visual salience manipulation in an eye-tracking boundary change paradigm would be both more natural and more sensitive. Unlike the self-paced reading paradigm, the entire sentence would be visible at once, and re-reading would be possible. Eye movement data are finer-grained, which would enable a more conclusive determination of how strong the interaction effect is. The follow-up study would differ from Winskel's boundary change experiment (2011), because Winskel's manipulation was to change the grapheme identity that was visible in the parafovea, but they did nothing to manipulate visual salience. Even if the vowels in VOP were not used for lexical identification, they might still have been used as gross visual cues. A preview of the wrong vowel might provide the same kind of gross visual cue that the present study finds may benefit reading Thai without space punctuation. By using a shrinking manipulation, the grapheme identity does not change, but only its salience does.

The mis-segmentation condition as implemented in the present study (which did not change spacing between words but rather only the timing that the letters were visible) would not be necessary or even relevant in an eye-tracking study, since the whole sentences would appear at once, inducing the natural challenge of needed to find word boundaries in space-less Thai text. The nearest analog to mis-segmentation in eye tracking would be inserting spaces in the wrong places (separating letters that belong to the same word). While such a manipulation might also be interesting to observe, it informs a different research question than the one posed here. Here we are concerned with isolating the effects of cues other than space. Winskel and colleagues (2009) concerned themselves with the presence or absence of an accurate cue. Studying the influence of a misinformative cue such as wrongly-placed spaces would merit a separate experiment altogether.

So far the introduction of (correctly-placed) space in normally spaceless Thai has been assumed to either be helpful or neutral, but future research must also consider the possibility that adding space between all words could hurt sentence processing. Recall that space, when added, did not necessarily help in reading Thai (Winskel, Radach, & Luksaneeyanawin, 2009). One possible explanation already given in this paper is that one informative cue (visual salience of letters in VOP) **helps**, while adding a second informative cue (space) provides **no additional benefit**. One participant pointed out during the debriefing that he uses space to disambiguate or to parse the syntactic structure of complex sentences. Thus if space is introduced between all words, then space as a syntactic cue would be obscured. Consider the analogous case of the comma in English. When a comma is placed in a sentence, it groups ideas and can help the reader understand and parse the phrase-level structure. The comma would cease to be helpful in parsing phrase structure if it were inserted between every pair of words, even though it might facilitate word-level segmentation.

The ramification of this possibility is that it provides another reason why inserting spaces does not help in reading Thai. The reasoning behind the present study is that there might already be some cue that helps readers segment words, and therefore adding a second cue does not help. The rationale behind the comma analogy is contrary, or at least agnostic, to what cues might normally be available for word segmentation. Regardless of Thai word segmentation cues in the absence of spacing, undermining space as a phrasal cue (by adding space everywhere) might

worsen higher-level comprehension of the intended phrase structure. Further experimentation could determine the effect of space (presence or absence) on overall sentence comprehension.

# 5 Conclusion

The goal of this study was to isolate the effect that the letters in the visually salient Vertical Orthographic Position (VOP) have on the time course of reading sentences in Thai. Results from a self-paced reading study showed main effects of VOP letter size and of temporal grouping of letter presentation. Making the VOP letters small slowed down reading. Temporally mis-segmenting the letters so that letters from more than one word were visible at the same time also slowed reading. Experiencing both manipulations simultaneously produced a significant interaction, inducing a reduction in reading speed beyond the additive effects of each manipulation individually. This heretofore unobserved interaction supports the hypothesis that Thai readers use letters in VOP as a visual cue for word segmentation and, possibly, eye movement planning.

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Winskel, H., Radach, R., & Luksaneeyanawin, S. (2009). Eye movements when reading spaced and unspaced Thai and English: A comparison of Thai–English bilinguals and English monolinguals. *Journal of Memory and Language, 61*(3), 339-351. doi:10.1016/j.jml.2009.07.002

# 7 Appendix

## 7.1 Participant Information

### *7.1.1 Biographical Data*

| **Participant** | **Gender** | **Age** | **Handed** | **Vision** | **Highest Completed** |
|---|---|---|---|---|---|
| 1 | F | 20 | R | Corrected | Undergrad 2 years |
| 2 | F | 24 | R | Corrected | Grad |
| 3 | M | 20 | R | Normal | Undergrad 3 years |
| 4 | M | 27 | R | Corrected | Completed Grad |
| 5 | M | 25 | R | Corrected | Grad |
| 6 | F | 28 | R | Normal | Completed Grad |
| 7 | F | 21 | R | Corrected | Undergrad 2 years |
| 8 | F | 24 | R | Corrected | Grad |
| 9 | F | 29 | R | Corrected | Completed Grad |
| 10 | F | 36 | R | Normal | Grad |
| 11 | F | 31 | R | Corrected | Grad |
| 12 | M | 28 | R | Corrected | Undergrad 4 years |
| 13 | M | 22 | R | Normal | Undergrad 3 years |
| 14 | M | 26 | R | Normal | Grad |
| 15 | F | 19 | L | Normal | Undergrad 1 year |
| 16 | F | 28 | R | Corrected | Grad |
| 17 | F | 28 | R | Corrected | Completed Grad |
| 18 | M | 29 | R | Corrected | Completed Grad |
| 19 | F | 28 | R | Corrected | Grad |
| 20 | M | 30 | R | Normal | Grad |
| 21 | M | 27 | R | Corrected | Completed Grad |
| 22 | M | 18 | R | Corrected | High School |
| 23 | M | 36 | R | Corrected | Grad |
| 24 | F | 28 | R | Normal | Undergrad 4 years |

### *7.1.2 Language Background Data*

| Participant | Native Language | Father's Dominant Language | Mother's Dominant Language | Home Language | School Language | Age Began Studying English | Other Languages (Age) |
|---|---|---|---|---|---|---|---|
| 1 | Thai | - | - | - | Thai | - | Chinese (12) |
| 2 | Thai | Thai Chinese | Thai | Thai | Thai | 6 | French (18) |
| 3 | Thai | Thai | Thai | Thai | Thai; English | 7 | Chinese (16-18) |
| 4 | Thai | Thai | Thai | Thai | Thai | 11 | - |
| 5 | Thai | Thai | Thai | Thai | Thai | 9 | Chinese (16); Russian (21) |
| 6 | Thai | Thai | Thai | Thai | Thai | 9 | - |
| 7 | Thai | Thai | Thai | Thai | Thai | 10 | - |
| 8 | Thai | - | - | Chinese | English | - | - |
| 9 | Thai | - | - | Thai | - | 7 | - |
| 10 | Thai | Thai | Thai | Thai | Thai | 11 | - |
| 11 | Thai | - | - | - | Thai | - | French (16) |
| 12 | Thai | Thai | Thai | Thai | Thai | 10 | - |
| 13 | Thai | Thai | Thai | Thai | Thai (English) | - | - |
| 14 | Thai | Thai | Thai | Thai | Thai | 7 | - |
| 15 | Thai | Thai | Thai | Thai | Thai | 7 | - |
| 16 | Thai | Thai | Thai | Thai | Thai | 3 | - |
| 17 | Thai | Thai | Thai | Thai | Thai | 5 | German (15); Mandarin (19) |
| 18 | Thai | Thai | Thai | Thai | Thai | 11 | French (24) |
| 19 | Thai | Thai | Thai | Thai | Thai | 7 | Chinese (21) |
| 20 | Thai | Thai | Thai | Thai | Thai | 11 | |
| 21 | Thai | Thai | Thai | Thai | Thai | 12 | Chinese (17, studied for 2 years duration) |
| 22 | Thai | Thai | Thai | Thai | Thai; English | | French (17); German (18) |
| 23 | Thai | Thai | Thai | Thai | Thai | 7 | - |
| 24 | Thai | Thai | Thai | Thai | Thai | 12 | - |

## 7.2 Summaries of Mixed Effects Models

### *7.2.1 Full Mixed Effects Model*

```
Linear mixed model fit by maximum likelihood
Formula: durlog.preTargPost ~ shrunk + misseg + shrunk * misseg + (1 |
subj) + (1 | itemid)

   AIC   BIC logLik deviance REMLdev
 -2539 -2498   1276    -2553   -2523
Random effects:
 Groups   Name        Variance  Std.Dev.
 itemid   (Intercept) 0.0031671 0.056277
 subj     (Intercept) 0.0139843 0.118255
 Residual             0.0204335 0.142946
Number of obs: 2688, groups: itemid, 112; subj, 24

Fixed effects:
                    Estimate Std. Error t value
(Intercept)           3.074291   0.025325  121.39
shrunkTRUE            0.014768   0.007798    1.89
missegTRUE            0.070575   0.007798    9.05
shrunkTRUE:missegTRUE 0.023527   0.011029    2.13

Correlation of Fixed Effects:
            (Intr) shTRUE msTRUE
shrunkTRUE  -0.154
missegTRUE  -0.154  0.500
shTRUE:TRUE  0.109 -0.707 -0.707
```

### *7.2.2 Full Model without Interaction Term*

```
Linear mixed model fit by maximum likelihood
Formula: durlog.preTargPost ~ shrunk + misseg + (1 | subj) + (1 | itemid)

   AIC   BIC logLik deviance REMLdev
 -2536 -2501   1274    -2548   -2526
Random effects:
 Groups   Name        Variance  Std.Dev.
 itemid   (Intercept) 0.0031656 0.056263
 subj     (Intercept) 0.0139839 0.118253
 Residual             0.0204700 0.143073
Number of obs: 2688, groups: itemid, 112; subj, 24

Fixed effects:
            Estimate Std. Error t value
(Intercept) 3.068410   0.025172  121.90
shrunkTRUE  0.026531   0.005519    4.81
missegTRUE  0.082338   0.005519   14.92

Correlation of Fixed Effects:
           (Intr) shTRUE
shrunkTRUE -0.110
missegTRUE -0.110  0.000
```

### 7.2.3 Full Model without Segmentation or Interaction

```
Linear mixed model fit by maximum likelihood
Formula: durlog.preTargPost ~ shrunk + (1 | subj) + (1 | itemid)

   AIC   BIC logLik deviance REMLdev
 -2325 -2295   1167    -2335   -2321
Random effects:
 Groups   Name        Variance  Std.Dev.
 itemid   (Intercept) 0.0030912 0.055599
 subj     (Intercept) 0.0139673 0.118183
 Residual             0.0222545 0.149179
Number of obs: 2688, groups: itemid, 112; subj, 24

Fixed effects:
            Estimate Std. Error t value
(Intercept) 3.109579   0.025020  124.28
shrunkTRUE  0.026531   0.005755    4.61

Correlation of Fixed Effects:
           (Intr)
shrunkTRUE -0.115
```

### 7.2.4 Full Model without Shrinking or Interaction

```
Linear mixed model fit by maximum likelihood
Formula: durlog.preTargPost ~ misseg + (1 | subj) + (1 | itemid)

   AIC   BIC logLik deviance REMLdev
 -2515 -2486   1263    -2525   -2511
Random effects:
 Groups   Name        Variance  Std.Dev.
 itemid   (Intercept) 0.0031578 0.056195
 subj     (Intercept) 0.0139821 0.118246
 Residual             0.0206553 0.143719
Number of obs: 2688, groups: itemid, 112; subj, 24

Fixed effects:
            Estimate Std. Error t value
(Intercept) 3.081675   0.025021  123.16
missegTRUE  0.082338   0.005544   14.85

Correlation of Fixed Effects:
           (Intr)
missegTRUE -0.111
```

### 7.2.5 Full Model without any Fixed Effects (only Random of Subject & Item)

```
Linear mixed model fit by maximum likelihood
Formula: durlog.preTargPost ~ (1 | subj) + (1 | itemid)

   AIC   BIC logLik deviance REMLdev
 -2306 -2282   1157    -2314   -2308
Random effects:
 Groups   Name        Variance  Std.Dev.
 itemid   (Intercept) 0.0030835 0.055529
 subj     (Intercept) 0.0139656 0.118176
 Residual             0.0224398 0.149799
Number of obs: 2688, groups: itemid, 112; subj, 24

Fixed effects:
            Estimate Std. Error t value
(Intercept)  3.12284    0.02485   125.7
```

### 7.2.6 Full Model without Random Subject Factor

```
Linear mixed model fit by maximum likelihood
Formula: durlog.preTargPost ~ shrunk + misseg + shrunk * misseg + (1 |
itemid)

   AIC   BIC logLik deviance REMLdev
 -1258 -1223    635    -1270   -1239
Random effects:
 Groups   Name        Variance  Std.Dev.
 itemid   (Intercept) 0.0025261 0.050261
 Residual             0.0350054 0.187097
Number of obs: 2688, groups: itemid, 112

Fixed effects:
                     Estimate Std. Error t value
(Intercept)           3.07429    0.00864   355.8
shrunkTRUE            0.01477    0.01021     1.4
missegTRUE            0.07057    0.01021     6.9
shrunkTRUE:missegTRUE  0.02353    0.01443     1.6

Correlation of Fixed Effects:
            (Intr) shTRUE msTRUE
shrunkTRUE  -0.591
missegTRUE  -0.591  0.500
shTRUE:TRUE  0.418 -0.707 -0.707
```

### *7.2.7 Full Model without Random Item Factor*

```
Linear mixed model fit by maximum likelihood
Formula: durlog.preTargPost ~ shrunk + misseg + shrunk * misseg + (1 |
subj)

   AIC   BIC logLik deviance REMLdev
 -2329 -2294   1171    -2341   -2312
Random effects:
 Groups   Name        Variance Std.Dev.
 subj     (Intercept) 0.013929 0.11802
 Residual             0.023603 0.15363
Number of obs: 2688, groups: subj, 24

Fixed effects:
                     Estimate Std. Error t value
(Intercept)          3.074291   0.024807  123.93
shrunkTRUE           0.014768   0.008381    1.76
missegTRUE           0.070575   0.008381    8.42
shrunkTRUE:missegTRUE 0.023527   0.011853    1.98

Correlation of Fixed Effects:
            (Intr) shTRUE msTRUE
shrunkTRUE  -0.169
missegTRUE  -0.169  0.500
shTRUE:TRUE  0.119 -0.707 -0.707
```

## 7.3 Target + Neighbors, by Item

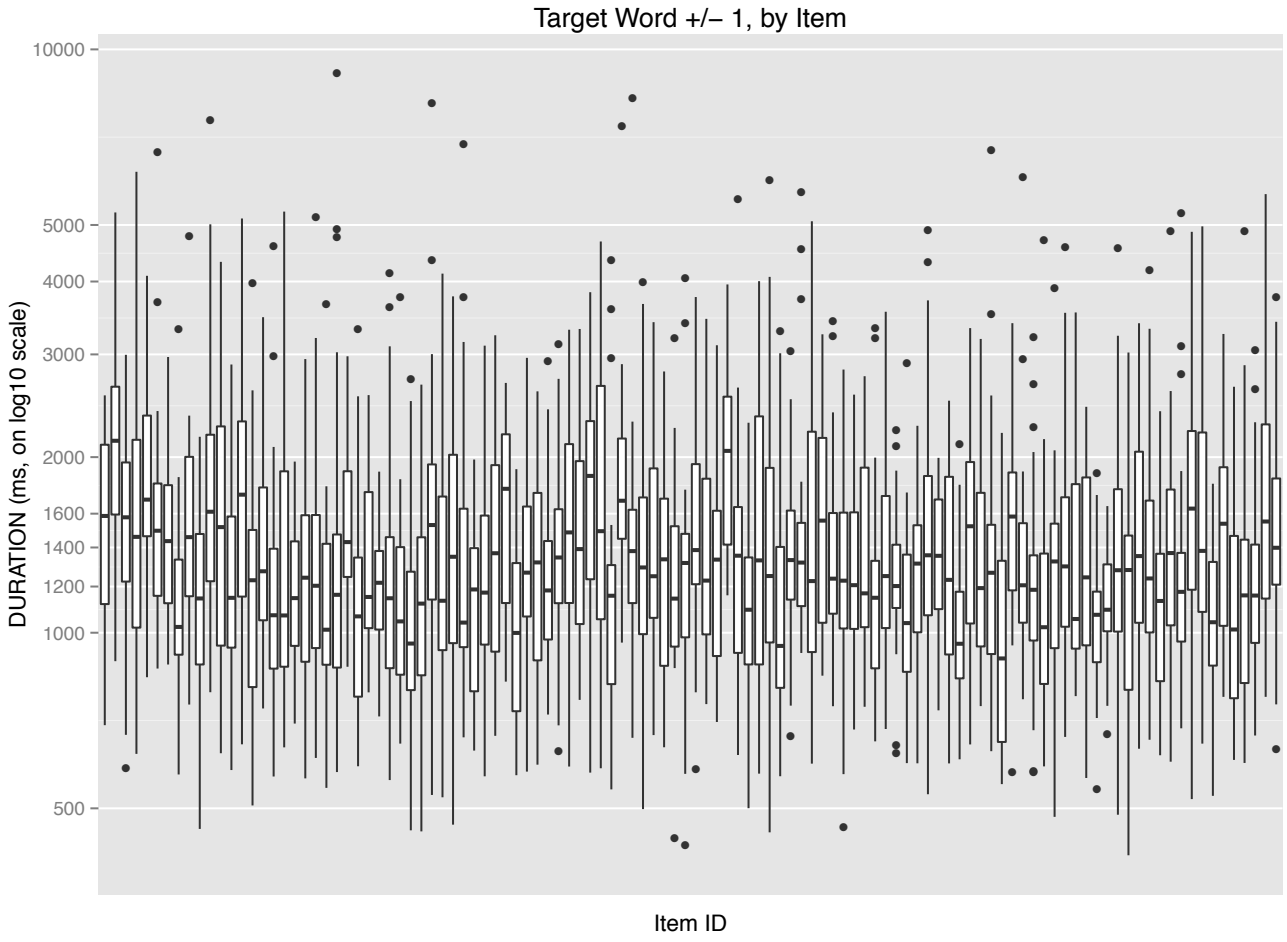


**Figure 14. Boxplots of all items**

Figure 14 does not indicate any individual items as outliers requiring more or less time to read the target region.

## 7.4 Target + Neighbors, by Subject

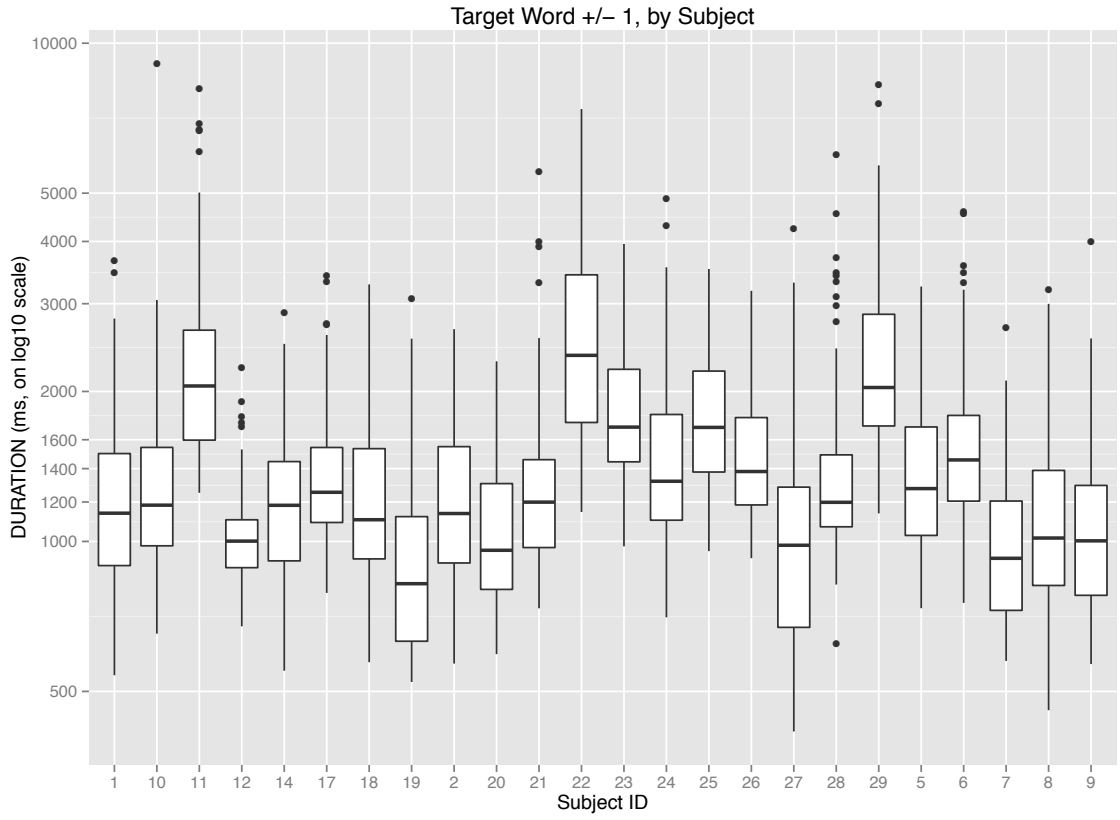


**Figure 15**

Boxplots of log-transformed target region durations.

## 7.5 Target Sentences

Each target sentence is shown below in Thai. Slashes "/" separate regions, and parentheses mark the target words.

1. การเลื่อนชั้น/ทาง/(สังคม)/ปัจจุบัน/ยังคง/ใช้/เส้น/ทาง/การศึกษา/และ/การเมือง/เป็น/หลัก
2. บริษัท/คอมพิวเตอร์/หลาย/แห่ง/ได้/มี/การลงทุน/(พัฒนา)/และ/วิจัย/เกี่ยว/กับ/คอมพิวเตอร์/ช่วย/สอน
3. การคิดคำนึงถึง/สังคม/(อุดมคติ)/เป็น/แนวทาง/ที่/ดี/ใน/การพัฒนา/หนทาง/ใน/การประเมิน/สังคม/ของ/เรา/เอง
4. วงการ/อุตสาหกรรม/ที่มี/แนวคิด/แบบ/ระบบเศรษฐกิจ/แบบ(ทุนนิยม)/จะ/อาศัย/ประสิทธิภาพ/ใน/การทำงาน/เป็น/สำคัญ
5. วิธี/ง่ายๆ/ใน/การ(บำบัด)/น้ำเสีย/ที่/เป็น/ธรรมชาติ/มาก/ที่/สุดคือ/การใช้/จุลินทรีย์/บำบัด
6. การวิ่ง/รอบ/สนามหน้า/หมู่บ้าน/ถือ/เป็น/(กิจวัตร)/ประจำวัน/ของเขา
7. พนักงาน/ขับรถ/ลืม/(กุญแจ)/บ้าน/ไว้/ที่/สำนักงาน/ของ/ลูกค้า/หลังจาก/ไป/ส่ง/สินค้า
8. เรา/สามารถ/พัฒนา/(ทักษะ)/การฟัง/โดย/การฝึกฝน/ตัวเอง/ให้/มี/สมาธิ/ใน/การฟัง
9. การใช้ช่วงเวลา/ที่ว่าง/(วิเคราะห์)/สิ่ง/ที่/ได้/รับฟัง/มา/และ/จดบันทึก/จะ/สามารถ/ช่วย/ให้/เรา/จดจำ/ได้/มาก/ขึ้น
10. รัฐบาล/(พิจารณา)/การตัด/งบประมาณ/ด้าน/การฝึกอบรม/และ/สัมมนา/ของ/ราชการ/ใหม่/อีก/ครั้งหนึ่ง
11. เด็ก/ไทย/มัก/จะ/ได้รับ/การอบรม/ให้/กตัญญู/ต่อ/(บุพการี)/ผู้/ที่/อุปการะ/เลี้ยงดู/มา
12. หน่วยงาน/รัฐ/ให้/การสนับสนุน/ช่วยเหลือ/โครงการ/(มูลนิธิ)/เด็ก/สานใจ/ช่วยภัย/น้ำท่วม
13. เรา/ควร/ออกกำลังกาย/บริโภค/อาหาร/ให้/ถูกสุขลักษณะ/และ/(พักผ่อน)/ให้เพียงพอ/เพื่อ/สุขภาพ/ที่/ดี
14. ประชาชน/(กังวล)/เรื่อง/การบริหาร/ประเทศ/ของ/รัฐบาล/ชุดนี้
15. การเปลี่ยนแปลง/การทำงาน/ของ/หุ่นยนต์/ค่อนข้าง/จำกัด/และ/(ยุ่งยาก)/เพราะ/เทคโนโลยี/ที่/ซับซ้อน
16. โรงเรียน/ขนาดเล็ก/และ/ขนาดกลาง/ใน/ปัจจุบัน/มี/(คุณภาพ)/ต่ำ/เพราะ/ขาดแคลน/ครู/ที่เก่ง/และ/ขาด/งบประมาณ
17. ถ้า/บิดา/หรือ/มารดา/เป็น/โรค/(ภูมิแพ้)/จะ/ทำ/ให้/บุตร/มี/โอกาส/เป็น/โรค/ภูมิแพ้/ประมาณ/ร้อยละ/สามสิบ/ถึง/ห้าสิบ
18. อาการ/สมาธิ/สั้น/ใน/เด็ก/ทำให้/มี/(ปัญหา)/การหลับ/ใน/เวลา/เรียน/ความคิด/ความจำสั้น/เรียน/และ/ทำงาน/ได้/ไม่เต็มที่
19. รัฐบาล/ได้/กำหนด/ให้/มี/นโยบาย/การแปลง/(สินทรัพย์)/เป็น/ทุน/ขึ้น/เพื่อ/เป็น/การสร้าง/โอกาส/ให้/แก่/ประชาชน
20. ทาง/โรงเรียน/จัด/ให้/นักเรียน/ได้/มี/โอกาส/ร่วม/กิจกรรม/ใน/ด้าน/การ(กีฬา)/โดย/การจัดงาน/กีฬาสี
21. ศาสนา/พุทธ/มี/(นิกาย)/ที่/สำคัญ/อยู่๒นิกาย/อัน/เกิด/จาก/การสังคายนา/ครั้งที่๒/เป็น/เหตุ/ให้/มีการถือ/พระวินัย/แตกต่างกัน
22. สติปัญญา/พัฒนาการ/มา/จาก/พฤติกรรม/ที่/เป็น/(รูปธรรม)/มอง/เห็น/ได้/ง่ายๆ
23. นักเรียน/ที่/สอบ/ได้/ที่/หนึ่ง/จะ/ได้/รับ/ทุน/การ/ศึกษา/และ/(วุฒิบัตร)/ใน/งาน/ประจำปี/โรงเรียน
24. ขนม/ช็อคโกแลต/ใน/ช่วง/วัน/อีสเตอร์/เป็น/รูป/ไข่/ข้าง/ใน/มัก/กลวง/ไว้/ใส่/ขนม/และ/(ลูกอม)/เพื่อ/มอบ/ให้/แก่/กัน
25. สิ่ง/ที่/สำคัญ/ต่อ/ผู้/ส่งออก/คือ/การ/บริหาร/ความ/เสี่ยง/จาก/(อัตรา)/แลก/เปลี่ยน/เงิน/ตรา/ต่างประเทศ
26. การ/ออกแบบ/(กังหัน)/ลม/ต้อง/อาศัย/ความ/รู้/ทาง/ด้าน/พลศาสตร์/ของ/ลม/และ/หลัก/วิศวกรรมศาสตร์/เพื่อ/ให้/ได้/กำลัง/งาน
27. การ/บำบัด/น้ำเสีย/โดย/การ/ใช้/กังหัน/น้ำ/ชัยพัฒนา/สามารถ/ปรับปรุง/(คุณภาพ)/น้ำ/ตาม/สถานที่/ต่างๆ/ทั่ว/ทุก/ภูมิภาค
28. ประชาชน/ใน/หลาย/จังหวัด/ได้/รับ/ความ/(เดือดร้อน)/จาก/สถานการณ์/น้ำท่วม/ที่/เกิด/จาก/พาย/โซน/ร้อน
29. ปัญหา/ที่/เกิด/จาก/(วิกฤต)/ความ/ขัดแย้ง/ทาง/การเมือง/ได้/ส่ง/ผล/กระทบ/อย่าง/มาก/ต่อ/ระบบ/เศรษฐกิจ/ของ/ชาติ
30. นักธรณีวิทยา/เจาะ/ชั้นดิน/เพิ่ม/อีก/หลาย/จุด/ใน/(สัปดาห์)/หน้า/เพื่อ/หา/สาเหตุ/แผ่นดิน/ทรุด/ใน/จังหวัด/อ่างทอง
31. ปัญหา/(น้ำท่วม)/ขัง/ใน/กรุงเทพมหานคร/เกิด/จาก/คัน/กั้นน้ำ/ที่/ทำให้/น้ำ/ไม่/สามารถ/ระบาย/ได้/ตาม/ธรรมชาติ
32. ร้าน/ขาย/กาแฟ/และ/อาหาร/ว่าง/ที่/(วิทยาลัย)/การ/อาชีพ/เป็น/ร้าน/ที่/เปิด/ขาย/โดย/นักศึกษา
33. เสียง/ใน/ภาษา/หมายถึง/เสียง/ที่/มนุษย์/เปล่ง/ออก/มา/เพื่อ/สื่อ/ความหมาย/สื่อ/ความ/เข้าใจ/ติดต่อ/(สื่อสาร)/ระหว่าง/กัน
34. ชาว/ต่างชาติ/มัก/มอง/ว่า/คนไทย/เรา/มัก/ทำ/ไม่/ค่อย/(กำหนด)/ระยะเวลา/ใน/การ/ทำงาน/ไว้/ล่วงหน้า
35. ถ้า/บุคคล/มี/(ทัศนคติ)/บวก/ต่อ/สิ่งใด/ก็/จะ/มี/พฤติกรรม/ที่/จะ/เผชิญ/ต่อ/สิ่งนั้น
36. พนักงาน/ธนาคาร/จะ/ต้อง/มี/ความ/(ซื่อสัตย์)/ใน/การ/ปฏิบัติ/หน้าที่/ที่/ต้อง/รับผิดชอบ/ดูแล/เงิน/ของ/ลูกค้า
37. โรงงาน/ผลิต/(อุปกรณ์)/ของ/เครื่อง/คอมพิวเตอร์/นั้น/ต้อง/ใช้/สารเคมี/เป็น/จำนวน/มาก/ซึ่ง/จะ/ทำให้/เกิด/มลพิษ/ต่างๆ/มากมาย

38. ทัศนคติ/เป็น/แนวโน้ม/ที่/มี/อิทธิพล/ต่อ/พฤติกรรม/การ/ตอบสนอง/ต่อ/(สิ่งแวดล้อม)/หรือ/สิ่งเร้า
39. รัฐบาล/(มุ่งมั่น)/ที่/จะ/ช่วยเหลือ/และ/สนับสนุน/เกษตรกร/และ/เศรษฐกิจ/ภาคเกษตร/ใน/ชนบท/ให้/เติบโต/ได้/อย่าง/มั่นคง/ยั่งยืน
40. การ/สร้าง/ความ/เข้าใจ/ให้/แก่/พนักงาน/ทุก/ระดับ/ทั่ว/ทั้ง/องค์กร/เป็น/(ปัจจัย)/ของ/ความ/สำเร็จ/การ/บริหาร/องค์กร
41. แพทย์/มัก/จะ/ซัก/ประวัติ/ผู้ป่วย/อย่าง/ละเอียด/ใน/การ/(วินิจฉัย)/โรค/เบื้องต้น
42. คณะ/รัฐมนตรี/มี/มติ/อนุมัติ/โครงการ/(ศึกษา)/เบื้องต้น/การ/ก่อตัว/ของ/เมฆ/ที่/มี/ผล/กระทบ/ต่อ/สภาพ/อากาศ/ของ/ประเทศไทย
43. ผู้/จัดการ/ให้/พนักงาน/ฝ่าย/การตลาด/(สำรวจ)/ความ/ต้องการ/ของ/ผู้บริโภค
44. กฎหมาย/ห้าม/ผู้/ที่/อยู่/ใน/ภาวะ/ล้มละลาย/ทำ/(ธุรกรรม)/ใดๆ/ทั้งสิ้น
45. ผู้/ที่/จะ/มา/เป็น/พนักงาน/สอบสวน/ต้อง/เป็น/ผู้/มี/(คุณธรรม)/สูง/จิตใจ/ดี/หนักแน่น/และ/อดทน
46. ใน/ช่วง/ภาวะ/เงินเฟ้อ/ประชาชน/มัก/จะ/กักตุน/สินค้า/(อุปโภค)/บริโภค/ไว้/เนื่องจาก/สินค้า/อยู่/ใน/ภาวะ/ข้าวยาก/หมากแพง
47. ตลาด/ที่/มี/ผู้/ผลิต/เพียง/ราย/เดียว/เป็น/ลักษณะ/อย่าง/หนึ่ง/ของ/ตลาด/แบบ/(ผูกขาด)/ทาง/เศรษฐศาสตร์
48. โรงเรียน/ต่างๆ/ได้/จัด/ให้/มี/การ/สอน/วิชา/(ฟุตบอล)/ทำให้/เด็ก/ผู้หญิง/หัน/มา/เล่น/ฟุตบอล/กัน/มาก/ขึ้น
49. ชาว/พุทธ/จะ/ต้อง/ปฏิบัติ/ตน/เป็น/คนดี/มี/(ศีลธรรม)/ประจำ/ใจ
50. มะเร็ง/ไต/พบ/มาก/ใน/ผู้/ที่/สูบ/(บุหรี่)/จัด/และ/อาจ/ลุกลาม/อย่าง/รวดเร็ว
51. ผู้ป่วย/ที่/พบ/(เนื้องอก)/ใน/ไต/ใน/ระยะ/เริ่มแรก/จะ/มี/ชีวิต/อยู่/ได้/อย่างน้อย/ห้า/ปี
52. ตำรวจ/ได้/ทำ/การ/ปิดล้อม/สถาน/(บันเทิง)/หลัง/ได้/รับ/แจ้ง/ข่าว/ว่า/มี/วัยรุ่น/ทะเลาะ/เบาะแว้ง/กัน
53. ชาว/อังกฤษ/ต่อ/แถว/เติม/น้ำมัน/หลัง/จาก/พนักงาน/(ขับรถ)/ขนส่ง/น้ำมัน/ประกาศ/แผน/หยุดงาน/ประท้วง
54. รัฐมนตรี/กระทรวง/พลังงาน/ปฏิเสธ/ข้อ/กล่าว/หา/ว่า/เป็น/สาเหตุ/ที่/ทำให้/ประชาชน/ตื่น/ตระหนก/จน/ต้อง/(กักตุน)/น้ำมัน
55. ความ/ตื่นตัว/ใน/นโยบาย/นำ/เทคโนโลยี/มา/ช่วย/(แก้ไข)/ปัญหา/สิ่งแวดล้อม/ทำให้/กรุง/ลอนดอน/มี/แผน/เพิ่ม/จำนวน/รถ/โดยสาร/ไฮบริด
56. ใน/ฤดู/ทำนา/ชาวนา/จะ/มี/งาน/ทำ/ตลอด/แต่/หลังจาก/(เก็บเกี่ยว)/แล้ว/ชาวนา/ก็/ไม่/มี/งาน/ทำ/เป็น/หลักแหล่ง/แน่นอน
57. อุณหภูมิ/ที่/สูง/ขึ้น/อาจ/ทำให้/ภูเขา/หิมะ/(พังทลาย)/ลง/มา/ได้
58. ถุงลม/นิรภัย/เป็น/อุปกรณ์/ที่/ใช้/ลด/ความ/รุนแรง/จาก/(อันตราย)/ที่/อาจ/เกิด/จาก/อุบัติเหตุ/ที่/มี/ต่อ/ผู้/ขับขี่/รถยนต์
59. สัญญา/ซื้อ/ขาย/ที่ดิน/จะ/มี/ผล/สมบูรณ์/เมื่อ/ผู้/ซื้อ/และ/ผู้/ขาย/ได้/ลง/นาม/ต่อ/หน้า/(เจ้าหน้าที่)/กรม/ที่ดิน
60. เขา/ได้/ย้าย/เครื่องใช้/ไฟฟ้า/ที่/ยก/ได้/ขึ้น/ชั้น/สอง/(เรียบร้อย)/แล้ว/ก่อน/ที่/น้ำ/จะ/เข้า/บ้าน
61. ภูมิปัญญา/ใน/การ/รักษา/โรค/คือ/ภูมิปัญญา/ที่/ใช้/ใน/การ/(ดูแล)/รักษา/และ/แก้/ปัญหา/สุขภาพ/เช่น/การ/ใช้/สมุนไพร/เป็น/ยา/และ/อาหาร
62. ห้องสมุด/ได้/ทำ/การ/ปิด/ให้/บริการ/(ชั่วคราว)/ใน/ช่วง/ปิดเทอม/เพื่อ/การ/ซ่อมแซม/ปรับปรุง
63. ประชาชน/ขอ/ให้/ส่วน/ราชการ/เร่ง/(ดำเนินการ)/ยื่น/ขอ/รับ/และ/เบิก/เงิน/ช่วยเหลือ/สำหรับ/ผู้/เกษียณ/ก่อน/กำหนด
64. ถ้า/สมุด/(บัญชี)/เงิน/ฝาก/หาย/ต้อง/ดำเนินการ/แจ้งความ/และ/นำ/บันทึก/ประจำวัน/ไป/เป็น/หลักฐาน/ให้/เจ้าหน้า/ที่/ธนาคาร
65. สำนักงาน/ตำรวจ/แห่ง/ชาติ/มี/มติ/ยกเลิก/การ/สอบ/ตำรวจ/ชั้น/ประทวน/ทั่ว/ประเทศ/หลัง/พบ/การ/(ทุจริต)/หลาย/พื้นที่
66. การ/เกิด/(อุทกภัย)/คือ/ภัย/และ/อันตราย/ที่/เกิด/จาก/สภาวะ/น้ำท่วม/หรือ/น้ำท่วม/ฉับพลัน
67. บ้าน/เรือน/หรือ/อาคาร/สิ่ง/ก่อ/สร้าง/ที่/ไม่/(แข็งแรง)/จะ/ถูก/กระแสน้ำ/ที่/ไกล/เชี่ยว/พังทลาย/ได้
68. ทาง/จังหวัด/กำลัง/ทำ/การ/ซ่อมถนน/สะพาน/และ/ทาง/รถไฟ/ที่/ขาดตอน/(ชำรุด)/เสียหาย/ให้/กลับ/สู่/สภาพเดิม
69. ความ/รู้/ไม่/จำเป็น/ต้อง/อยู่/ใน/(ตำรา)/หรือ/ใน/ระบบ/การ/ศึกษา/เท่านั้น/เรา/รู้/จัก/ค้นคว้า/หา/ความรู้/รอบตัว/ไว้/ด้วย
70. ส่วนมาก/พ่อแม่/จะ/สอน/ให้/ลูก/เริ่ม/อ่าน/หนังสือ/โดย/การ/อ่าน/(นิทาน)/อีสป
71. คน/ที่/อยู่/ต่าง/จังหวัด/จะ/(สัมผัส)/อากาศ/หนาว/ได้/มากกว่า/ใน/กรุงเทพฯ
72. หิมะ/สามารถ/เกิด/ขึ้น/ได้/หาก/ใน/บรรยากาศ/ขณะนั้น/มี/อุณหภูมิ/และ/ความชื้น/(สัมพัทธ์)/ที่/เหมาะสม
73. ความ/เห็น/ทั้งหมด/ใน/เวป/นี้/เป็น/เพียง/(มุมมอง)/ส่วนตัว/บน/พื้นฐาน/ความคิด/ของ/นักลงทุน/รายย่อย/คน/นึง
74. คน/สุจริต/จึง/เป็น/คน/ที่/สังคม/(เชื่อถือ)/และ/กลาย/เป็น/ความ/ยอมรับ/นับถือ/ใน/ที่/สุด
75. ประชาชน/เดินทาง/มา/เลือก/ซื้อ/สินค้า/ที่/จำเป็น/กัน/ใน/งาน/มหกรรม/ธง/ฟ้า/กัน/อย่าง/(คับคั่ง)/ตลอด/ทั้ง/วัน
76. สินค้า/ไทย/ที่/มี/วาง/(จำหน่าย)/ใน/ยุโรป/ไม่/ได้/รับ/ผล/กระทบ/จาก/วิกฤต/เศรษฐกิจ
77. ทหาร/ผ่าน/ศึก/ได้/รับ/ยกย่อง/ว่า/เป็น/(วีรบุรุษ)/ของ/ชาติ
78. ดอก/ลีลาวดี/เป็น/(สัญลักษณ์)/ของ/วัน/งด/สูบ/บุหรี่/โลก
79. กรม/ทรัพย์สิน/ทาง/(ปัญญา)/เสริมสร้าง/ขีด/ความ/สามารถ/ใน/การ/แข่งขัน/ทาง/การค้า/โดย/ให้/มี/การ/จด/สิทธิบัตร

80. กีฬา/ฟุตบอล/ก็/คง/เป็น/(สินค้า)/อีก/ตัว/หนึ่ง/ที่/ส่ง/ออก/มา/เพื่อ/ทำ/เงิน/ไม่/ต่าง/จาก/สินค้า/ส่ง/ออก/อื่นๆ
81. สนธิ/สัญญา/กรุง/เบิร์น/เป็น/สนธิ/สัญญา/ว่า/ด้วย/การ/คุ้มครอง/(ลิขสิทธิ์)/ระหว่าง/ประเทศ
82. ประเทศไทย/มี/รูปแบบ/รัฐ/เป็น/ราชาธิปไตย/ภาย/ใต้/(รัฐธรรมนูญ)/และ/ปกครอง/ใน/ระบอบ/ประชาธิปไตย/แบบ/รัฐสภา
83. ศาล/รัฐธรรมนูญ/เป็น/องค์กร/หลัก/ที่/ทำ/หน้าที่/ตี/ความ/รัฐธรรมนูญ/และ/วินิจฉัย/ข้อ/(ขัดแย้ง)/ข้อ/พิพาท/ที่/เกี่ยวข้อง/กับ/รัฐธรรมนูญ
84. ปัจจุบัน/สรรพากร/ได้/ให้/บริการ/การ/ออก/หนังสือ/(รับรอง)/การ/เสีย/ภาษี/และ/การ/มี/ถิ่น/ที่/อยู่/เป็น/ภาษา/อังกฤษ/ให้/กับ/ผู้/เสีย/ภาษี
85. เขา/ไป/ยื่น/(คำร้อง)/กับ/งาน/บัณฑิต/เพื่อ/ขอ/เก็บ/ข้อมูล/ประกอบ/การ/ทำ/วิทยานิพนธ์
86. ชาว/ล้านนา/มี/วิธี/การ/ทำ/(น้ำพริก)/หลาย/วิธี/ซึ่ง/แตกต่าง/กัน/ไป/ตาม/ความ/นิยม/ของ/แต่/ละ/ท้องถิ่น
87. คน/ที่/มี/ความ/เสมอ/ต้น/เสมอ/ปลาย/จะ/ได้/รับ/ความ/เชื่อถือ/อย่าง/สูง/และ/ให้/ความ/(นับถือ)/ที่/ถาวร/ด้วย
88. คน/ไทย/นิยม/(รับประทาน)/นำ้พริก/หนุ่ม/คู่/กับ/แคบหมู/และ/ผัก/สด
89. ทุกคน/มุ่งหวัง/ที่/จะ/มี/(กิจการ)/เป็น/ของ/ตัวเอง
90. งาน/นี้/ได้/ให้/โอกาส/เขา/(พิสูจน์)/ฝีมือ/ให้/เป็น/ที่/ประจักษ์/แก่/ทุก/คน
91. รัฐธรรมนูญ/เป็น/กฎหมาย/สูง/สุด/ของ/รัฐ/ที่/มี/ความ/(ศักดิ์สิทธิ์)/และ/คง/ทน/ถาวร
92. ที่/ปรึกษา/การ/ขาย/ร่วม/แสดง/ความ/(ยินดี)/พร้อม/ส่ง/มอบ/เงิน/รางวัล/ให้/กับ/พนักงาน/ขาย/ดี/เด่น
93. ปัญหา/(หัวหน้า)/งาน/กับ/ลูก/น้อง/ดู/เหมือน/ว่า/จะ/เป็น/ปัญหา/ที่/เกิด/ขึ้น/ใน/ทุก/องค์กร
94. วิถี/การ/(ดำรงชีพ)/คือ/อีก/หนึ่ง/ปัญหา/สำคัญ/ที่/ชุมชน/ได้/รับ/ผล/กระทบ/ภาย/หลัง/ที่/มี/การ/จัด/ตั้ง/อุทยาน/แห่ง/ชาติ/เขา/ใหญ่
95. ไตรยางศ์/หรือ/(อักษร)/สาม/หมู่/คือ/ระบบ/การ/จัด/หมวด/หมู่/อักษร/ไทย/ตาม/ลักษณะ/การ/ผัน/วรรณยุกต์
96. คน/ส่วน/ใหญ่/วิพากษ์/(วิจารณ์)วิธีการ/สลาย/ม็อบ/ของ/ตำรวจ/ว่า/กระทำ/รุนแรง/กว่า/เหตุ
97. ความ/ซุกซน/(ดื้อรั้น)/เอา/แต่/ใจ/ตัว/เอง/ของ/เขา/เป็น/อุปนิสัย/ที่/สะสม/มา/ตั้งแต่/เล็ก/จน/กระทั่ง/เติบโต/เป็น/หนุ่ม
98. เพชรบูรณ์/ระดม/กำลัง/เจ้าหน้าที่/(ตำรวจ)/เข้า/แก้ไข/ปัญหา/การจราจร/อย่าง/เต็มที่/โดย/เฉพาะ/ชั่วโมง/เร่งด่วน
99. ตุ๊กตา/ประเภท/นี้/ประดิษฐ์/ขึ้น/เพื่อ/ให้/เด็ก/เล่น/มัก/ทำ/อย่าง/ง่ายๆ/จาก/(วัสดุ)/ที่/หา/ได้/ตาม/ธรรมชาติ
100. จิตรกรรม/เป็น/งาน/(ศิลปะ)/ที่/แสดง/ออก/ด้วย/การ/วาด/ระบาย/สี/และ/การ/จัด/องค์ประกอบ/ความ/งาม/อื่น/เพื่อ/ให้/เกิด/ภาพ/สอง/มิติ
101. กรม/สรรพากร/เป็น/ส่วน/ราชการ/ระดับ/กรม/(สังกัด)/กระทรวง/การ/คลัง/ที่/มี/หน้าที่/ใน/การ/จัด/เก็บ/ภาษี
102. ใน/ปัจจุบัน/(ดินสอ)/ผลิต/โดย/การ/ใส่/แกรไฟต์/กับ/ผง/ถ่าน/เติม/น้ำ/ลง/ไป/ผสม/แล้ว/ทำ/ให้/เป็น/แท่ง/ก่อน/จะ/เผา/ใน/เตา/ให้/แข็ง
103. ดินสอ/เป็น/(สิ่งประดิษฐ์)/ที่/ทำ/ด้วย/ไม้/แท่ง/เล็กๆ/ยาว/ประมาณ/เจ็ด/นิ้ว/บรรจุ/ภาย/ใน/ด้วย/แกรไฟต์
104. เรา/ใช้/ประโยชน์/(กำมะถัน)/ใน/อุตสาหกรรม/ได้/มาก/มาย/อาจ/จะ/กล่าว/ได้/ว่า/มัน/มี/ความ/สำคัญ/มาก/ต่อ/เศรษฐกิจ/โลก
105. นักเรียน/ที่/จบ/(มัธยม)/ต้น/ต่าง/มุ่งมั่น/ที่/จะ/สอบ/เข้า/เรียน/ต่อ/ใน/มหาวิทยาลัย
106. เรา/จำเป็น/ต้อง/(มัธยัสถ์)/เพื่อ/ให้/ราย/ได้/พอ/กับ/ราย/จ่าย/และ/เหลือ/เก็บ/ออม
107. คน/เรา/จะ/เป็น/อะไร/ให้/ดี/ต้อง/มี/(วินัย)/ถ้า/ไม่มี/วินัย/เป็น/อะไร/ก็/ไม่/ดี/ทั้งนั้น/
108. พระภิกษุ/สามเณร/ใน/ทาง/พระพุทธศาสนา/เป็น/ที่/กราบ/ไหว้/(สักการะ)/บูชา/ของ/บรรดา/พุทธศาสนิกชน
109. นัก/ศึกษา/ปริญญา/โท/จะ/ต้อง/ทำ/(วิทยานิพนธ)์/เพื่อ/ศึกษา/ค้นคว้า/หา/ความรู้/เกี่ยว/ก่อน/จบ/การ/ศึกษา
110. ออกซิเจน/มี/การ/หมุนเวียน/เป็น/(วัฏจักร)/โดย/การ/สังเคราะห์/แสง/จาก/พืช
111. พืช/ใช้/พลังงาน/แสง/และ/คลอโรฟิลล์/ใน/การ/(สังเคราะห์)/ด้วย/แสง/เพื่อ/จะ/ได้/สาร/อินทรีย์/เป็น/สาร/อาหาร
112. สิ่งมีชีวิต/ใน/ระบบ/(นิเวศ)/มี/บทบาท/และ/ความ/สำคัญ/แตกต่าง/กัน/ได้แก่/ผู้/ผลิต/และ/ผู้/บริโภค